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Estimated daily average per capita water ingestion by child and adult age categories based on USDA's 1994–1996 and 1998 continuing survey of food intakes by individuals

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Water ingestion estimates are important for the assessment of risk to human populations of exposure to water-borne pollutants. This paper reports mean and percentile estimates of the distributions of daily average per capita water ingestion for a number of age range groups. The age ranges, based on guidance from the US EPA's Risk Assessment Forum, are narrow for younger ages when development is rapid and wider for older ages when the rate of development decreases. Estimates are based on data from the United States Department of Agriculture's (USDA's) 1994–1996 and 1998 Continuing Survey of Food Intake by Individuals (CSFII). Water ingestion estimates include water ingested directly as a beverage and water added to foods and beverages during preparation at home or in local establishments. Water occurring naturally in foods or added by manufacturers to commercial products (beverage or food) is not included. Estimates are reported in milliliters (ml/person/day) and milliliters per kilogram of body weight (ml/kg/day). As a by-product of constructing estimates in terms of body weight of respondents, distributions of self-reported body weights based on the CSFII were estimated and are also reported here.
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Introduction

This paper presents estimates of per capita community and total water ingestion by age range categories for the population of the United States using data collected in the USDA's 1994–1996 and 1998 Continuing Survey of Food Intakes by Individuals (CSFII, see USDA/ARS, 2000). Community water is tap water obtained from a community or municipal water supply, and total water is water obtained from all sources. The results presented emphasize ingestion by children within small age range categories, although results for adults within broader age categories are included. For each age range, the estimated mean, 90th and 95th percentiles of the distribution of average daily per capita ingestion of water are reported in milliliters (ml/person/day) and milliliters per kilogram of body weight (ml/kg/day). The motivation for producing estimates by smaller age categories, especially for children, is twofold. First, children as a group are considered a sensitive population, because they can be more susceptible to diseases caused by exposure to toxicants. Presidential Executive Order 13045 directs all Federal agencies to ensure that disproportionate risk to children is addressed and increased emphasis on early life exposure to carcinogens is provided in US EPA (2005a). Because water ingestion is a route of possible exposure to toxins, estimates of water ingestion by children are required for risk assessments. Second, the USDA's 1998 CSFII added data for more than 5000 children aged 9 years and younger. The larger sample size supported the generation of more precise estimates of water ingestion for children.

The age ranges for which estimates are presented are children younger than 1 month, 1 to < 3 months, 3 to <6 months, 6 to <12 months, 1 to <2 years of age, 2 to <3 years, 3 to <6 years, 6 to <11 years, 11 to <16 years, 16 to <18 years, 18 to <21 years, 21 years of age and older, and 65 years and older. The children's age groupings presented are identified in US EPA (2005b). In general, age groupings are narrow at younger ages when rapid developmental changes occur and broader at older ages when developmental rates decrease.

Methodology

Mean and percentile estimates of daily average per capita water ingestion were made using ingestion data collected in the USDA's 1994–1996 and 1998 CSFII, which is a multistage

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probability sample survey of individuals within US households. In the CSFII, two nonconsecutive days of food and beverage intake data were collected from a sample of more than 20,000 individuals in the 50 States and the District of Columbia. For both days, dietary recall information, including water intake, was collected by an in-home interviewer. The day 2 interview occurred 3–10 days after the day 1 interview but not on the same day of the week. Proxy interviews were conducted for children aged 6 years and younger, and individuals unable to report due to mental or physical limitations.

A series of CSFII records were used to determine the total amount of water ingested by each survey participant for the 2-day survey period. Total water ingestion is the sum of water ingested directly as a beverage and indirectly from food and drink. Direct water is water that survey respondents reported drinking directly as a beverage. Indirect water is defined as water added to foods or beverages during final preparation at home or by local food service establishments such as school cafeterias and restaurants. CSFII recipe files served as the basis for determining the percentage of indirect water contained per 100 g of each food consumed by participants. This percentage was then multiplied by the amount of food consumed by the survey respondents to determine the amount of indirect water ingested. Daily average per capita water ingestion, the basic unit for estimation, for each survey participant is the total water ingested, by source, over the 2-day survey period divided by 2. Indirect water does not include intrinsic water or water added by a manufacturer. Intrinsic water is biological water that is contained naturally in foods. Commercial water is water added to foods and beverages by the manufacturer prior to merchandizing. An example of commercial water is water added to bottled iced tea by the manufacturer.

Empirical distributions of daily average per capita water ingestion were constructed using the survey-weighted amount of daily average direct and indirect water ingested by survey respondents. Our general approach is comparable to that of Ershow and Cantor (1989) who used food consumption survey data collected by USDA in 1978 to estimate distributions of water ingestion. Standard statistical methods for the analysis of sample survey data (Hanson et al., 1953; Woodruff, 1971; Cochran, 1977; Kennedy and Gentle, 1980) were used for the analysis of the CSFII survey data to estimate means and estimates of percentiles of distributions of water ingestion. Standard methods were also used to construct 90% confidence limits for the estimated distribution means and 90% bootstrap limits for the estimated distribution percentiles. These methods are described in detail in US EPA (2000, 2004). Estimates are reported for ''all individuals'' and for ''consumers only.'' Estimates reported as ''all individuals'' include all survey respondents whether they reported ingesting any water or not during the 2-day survey period. That is, mean daily average per capita ingestion is averaged over all individuals sampled in the age group whether they report water ingestion or not. Ingestion estimates labeled as ''consumers only'' are generated from only the respondents who reported ingestion of water at least once during the 2-day survey period. Estimates for ''consumers only'' are often the primary focus in analyses of risk due to ingestion of water that may be contaminated.

The number of individuals sampled in the CSFII in each age category and the estimated number of individuals in the US population in each age category that the sampled individuals represent are shown in Table 1.

Results

Mean and percentile estimates derived from the CSFII sample data of daily average water ingestion in units of

Table 1. Sample sizes and population estimates by age category.

	''All individuals''		''Consumers only'' total water		''Consumers only'' community water	
Age group	Sample size	Population (000 s)	Sample size	Population (000 s)	Sample size	Population (000 s)
Less than 1 month	91	218	58	129	40	85
1 to <3 months	253	666	178	442	114	274
3 to <6 months	428	1073	363	901	281	698
6 to <12 months	714	1865	667	1742	562	1437
1 to <2 years	1040	4184	1017	4095	916	3683
2 to <3 years	1056	4036	1051	4019	934	3595
3 to <6 years	4391	12,377	4350	12,280	3960	11,266
6 to <11 years	1670	19,512	1659	19,389	1555	18,148
11 to <16 years	1005	19,262	1000	19,179	937	17,926
16 to <18 years	363	7773	357	7616	341	7174
18 to <21 years	389	10,030	383	9860	364	9255
21 years and older	9207	180,901	9178	180,232	8505	168,911
65 years and older	2170	31,043	2167	30,998	1958	28,167
All ages	20,607	261,897	20,261	259,883	18,509	242,451

Data source: 1994–1996 and 1998 USDA Continuing Survey of Food Intakes by Individuals (CSFII).

Table 2. Estimated direct[a] and indirect[b] community water ingestion (ml/person/day).

	All individuals[c]			Consumers only[d]		
		Percentile			Percentile	
Age	Mean (90% CI)[e]	90th (90% BI)	95th (90% BI)	Mean (90% CI)[e]	90th (90% BI)	95th (90% BI)
<1 month	184 (117–251)	687[e] (552–798)	839[e] (638–859)	470 (362–579)	849[e] (745–859)	858[e] (856–957)
1 to <3 months	227 (180–274)	804 (696–878)	896[e] (878–1022)	552 (504–600)	943[e] (881–1042)	1053[e] (954–1248)
3 to <6 months	362 (322–401)	928 (882–963)	1056 (1043–1170)	556 (511–600)	1021 (963–1068)	1171[e] (1068–1406)
6 to <12 months	360 (328–392)	885 (849–969)	1055 (1008–1254)	467 (436–499)	971 (886–1032)	1147 (1032–1304)
1 to <2 years	271 (253–289)	624 (601–709)	837 (754–925)	308 (289–326)	674 (598–735)	893 (772–987)
2 to <3 years	317 (298–337)	683 (649–706)	877 (828–939)	356 (337–375)	700 (674–754)	912 (834–947)
3 to <6 years	380 (365–394)	834 (815–893)	1078 (1053–1109)	417 (402–433)	867 (828–927)	1099 (1057–1173)
6 to <11 years	447 (417–476)	980 (943–1022)	1235 (1148–1317)	480 (450–511)	994 (954–1053)	1251 (1183–1322)
11 to <16 years	606 (562–651)	1387 (1291–1458)	1727 (1615–1780)	652 (607–696)	1.432 (1300–1549)	1744 (1615–2050)
16 to <18 years	731 (633–828)	1562 (1504–1817)	1983[e] (1843–2128)	792 (697–886)	1647 (1479–1843)	2002 (1890–2256)
18 to <21 years	826 (746–906)	1770 (1549–2105)	2540[e] (1908–2934)	895 (812–977)	1.860 (1570–2366)	2565[e] (2105–3363)
>21 years	1104 (1074–1134)	2230 (2195–2270)	2811 (2732–2924)	1183 (1153–1212)	2289 (2249–2318)	2848 (2818–2945)
>65 years	1127 (1073–1180)	2139 (2103–2186)	2551 (2500–2637)	1242 (1198–1285)	2190 (2152–2228)	2604 (2545–2645)
All ages	926 (903–949)	2014 (1996–2048)	2544 (2500–2584)	1000 (977–1023)	2069 (2026–2130)	2601 (2528–2707)

90% BI, 90% bootstrap interval about the estimated percentiles; 90% CI, 90% confidence interval about the estimated means.
Source of data: 1994–1996 and 1998 USDA Continuing Survey of Food Intakes by Individuals (CSFII). Estimates are based on 2-day (nonconsecutive) averages. Commercial (water added to foods and beverages by the manufacturer prior to merchandizing) and intrinsic water (water occurring naturally in foods) are excluded in the analyses.
[a]Direct water is defined as water ingested directly as a beverage.
[b]Indirect water is defined as water added in preparation of food or beverages.
[c]"All Individuals" include all participants whether or not they ingest any water from the specified source during the 2-day survey.
[d]"Consumers only" group excludes those who did not drink community water during the 2-day survey.
[e]The sample size does not meet minimum reporting requirements as described in the "Third Report on Nutrition Monitoring in the United States, 1994–96" (LSRO, 1995).

milliliters per person per day (ml/person/day) and milliliters per kilogram of body weight per day (ml/kg/day) are presented in Tables 2–6 for community water and total water by age category for male and female groups combined. A substantial number of additional tables that show estimates of ingestion by gender, source category and additional age categories in terms of ml/person/day and ml/kg/day are provided in US EPA (2004), which is available on the internet at the address indicated in the references. The emphasis here is on ingestion for the younger, small size age categories, although results are also included for adults and those who are 65 years and older. Water source categories are community water and total water. "Total water" includes water from all supply sources such as community, bottled, other and missing sources. "Community water" is tap water from a community or municipal water supply. "Bottled water" is plain water purchased in prepackaged containers, whereas "other water" is water from wells, springs and cisterns. The source identified as "missing" refers to water reported in the CSFII as ingested but with no identified source. Direct and indirect water are combined in the estimates. Direct water includes the amount of water ingested directly as a beverage and indirect water refers to water ingested indirectly through foods and beverages that had water added to them during final preparation at home or by local food service establishments. Commercial water added by a manufacturer, such as water contained in soda or beer and intrinsic water found naturally in foods and liquids such as milk, and natural undiluted juice are not included in these estimates.

Per Capita Water Ingestion: Fine Age Category Comparison (ml/person/day)

Estimates of daily average per capita community and total water ingestion are shown in Tables 2 and 3, respectively. On the basis of care takers' reporting, only 115 of the 253 surveyed children in this age group (1 to <3 months) or 45% ingested community water at least once during the 2-day survey period. Thus, estimates of daily average per capita community water ingestion based on the 114 "consumers only" sample are higher than those for "all individuals" in the age category 1 to <3 months. This is because no community water was ingested by the 139 of the sampled 253 children of this age category in the "all individuals" estimate. When amount of water ingested from all sources (i.e., total water) is estimated, the means and percentiles of daily average per capita total water ingestion presented in Table 3 are essentially the same for "all individuals" and "consumers only" older than 1 year of age. However, for children younger than 1 year of age, the "consumers only" ingest more water, on average, than the "all individuals" of the same age group. This is especially true for infants in

Table 3. Estimated direct[a] and indirect[b] total water[c] ingestion (ml/person/day).

	All individuals[c]			Consumers only[d]		
		Percentile			Percentile	
Age	Mean (90% CI)	90th (90% BI)	95th (90% BI)	Mean (90% CI)	90th (90% BI)	95th (90% BI)
<1 month	301 (215–387)	846[e] (638–859)	839[e] (638–859)	511 (417–606)	858[e] (856–993)	986[e] (974–1076)
1 to <3 months	368 (304–432)	889 (862–896)	896[e] (878–1022)	555 (487–622)	946[e] (891–1042)	1072[e] (1022–1183)
3 3 to <6 months	528 (485–571)	1025 (955–1083)	1056 (1043–1170)	629 (587–672)	1064 (1011–1177)	1330[e] (1183–1431)
6 to <12 months	530 (495–564)	1029 (973–1100)	1055 (1008–1254)	567 (534–600)	1050 (1001–1141)	1303 (1181–1372)
1 to <2 years	358 (338–377)	735 (686–778)	837 (754–925)	366 (346–385)	735 (715–765)	978 (915–1001)
2 to <3 years	437 (418–455)	825 (784–857)	877 (828–939)	439 (420–457)	825 (784–857)	1001 (944–1075)
3 to <6 years	514 (494–533)	980 (953–1004)	1078 (1053–1109)	518 (499–537)	980 (961–1000)	1206 (1171–1253)
6 to <11 years	600 (571–629)	1130 (1065–1162)	1235 (1148–1317)	603 (574–632)	1131 (1075–1162)	1409 (1336–1468)
11 to <16 years	834 (770–898)	1649 (1567–1775)	1727 (1615–1780)	837 (773–901)	1649 (1568–1749)	1961 (1873–2104)
16 to <18 years	964 (870–1057)	1842 (1743–1988)	1983[e] (1843–2128)	983 (896–1071)	1865 (1774–1982)	2346[e] (2129–2599)
18 to <21 years	1075 (980–1171)	2117 (1952–2299)	2540[e] (1908–2934)	1094 (999–1189)	2144 (1951–2299)	3002[e] (2576–3785)
>21 years	1466 (1427–1506)	2553 (2511–2607)	2811 (2732–2924)	1472 (1432–1512)	2559 (2522–2602)	3195 (3121–3363)
>65 years	1451 (1412–1489)	2323 (2279–2388)	2708 (2632–2760)	1453 (1415–1491)	2324 (2279–2388)	2708 (2636–2789)
All ages	1233 (1200–1265)	2341 (2303–2377)	2908 (2812–2975)	1242 (1210–1274)	2345 (2284–2403)	2923 (2842–2997)

90% BI, 90% bootstrap interval about the estimated percentiles; 90% CI, 90% confidence interval about the estimated means.
Source of data: 1994–1996 and 1998 USDA Continuing Survey of Food Intakes by Individuals (CSFII). Estimates are based on 2-day (nonconsecutive) averages. Commercial (water added to foods and beverages by the manufacturer prior to merchandizing) and intrinsic water (water occurring naturally in foods) are excluded in the analyses.
[a]Direct water is defined as water ingested directly as a beverage.
[b]Indirect water is defined as water added in preparation of food or beverages.
[c]"All individuals" include all participants whether or not they ingest any water from the specified source during the 2-day survey.
[d]"Consumers only" group excludes those who did not drink community water during the 2-day survey.
[e]The sample size does not meet minimum reporting requirements as described in the "Third Report on Nutrition Monitoring in the United States, 1994–96" (LSRO, 1995).

Table 4. Estimated direct and indirect community water ingestion based on body weight (ml/kg/day).

	All individuals			Consumers only		
		Percentile			Percentile	
Age	Mean (90% CI)	90th (90% BI)	95th (90% BI)	Mean (90% CI)	90th (90% BI)	95th (90% BI)
<1 month	52 (33–72)	196* (177–234)	232* (213–236)	137 (109–166)	235* (231–236)	238* (236–269)
1 to <3 months	48 (37–59)	151 (139–176)	205* (170–259)	119 (106–132)	228* (194–275)	285* (224–316)
3 to <6 months	52 (45–58)	135 (128–142)	159 (146–176)	80 (73–87)	148 (138–162)	173* (162–189)
6 to <12 months	41 (37–45)	102 (96–108)	126 (117–131)	53 (49–57)	112 (108–117)	129 (127–138)
1 to <2 years	23 (22–25)	53 (50–56)	71 (64–83)	27 (25–28)	56 (50–62)	75 (68–85)
2 to <3 years	23 (21–24)	50 (48–53)	60 (57–63)	26 (24–27)	52 (48–56)	62 (59–66)
3 to <6 years	22 (21–22)	48 (46–49)	61 (59–65)	24 (23–25)	49 (48–51)	65 (61–68)
6 to <11 years	16 (15–17)	34 (32–36)	43 (40–45)	17 (16–18)	35 (33–36)	45 (41–47)
11 to <16 years	12 (11–13)	25 (25–26)	34 (31–36)	13 (12–13)	26 (25–27)	34 (31–36)
16 to <18 years	11 (10–12)	23 (22–26)	31* (26–33)	12 (11–13)	24 (22–26)	32* (28–33)
18 to <21 years	12 (11–13)	27 (24–32)	35* (30–43)	13 (12–14)	29 (26–32)	35* (32–42)
>21 years	15 (15–15)	31 (31–32)	39 (38–39)	16 (16–16)	32 (31–32)	39 (39–40)
>65 years	16 (15–17)	31 (31–32)	37 (36–37)	18 (17–18)	32 (31–32)	37 (37–38)
All ages	16 (15–16)	32 (32–33)	43 (41–44)	17 (16–17)	33 (33–34)	44 (43–45)

See legend on Table 2.

the age categories of less than 1 month and 1 to <3months of age.

The mean daily average per capita community water ingestion across all ages is 926 ml/person/day. The 90% confidence interval around this estimated mean is 903–949 ml/person/day. The estimated 90th percentile from the empirical distribution of daily average per capita community water ingestion is 2014 ml/person/day and the 90% bootstrap confidence interval around this estimated 90th percentile is 1996–2048 ml/person/day (Table 2, below). See Efron and

Table 5. Estimated direct and indirect total water ingestion based on body weight (ml/kg/day).

	All individuals			Consumers only		
		Percentile			Percentile	
Age	Mean (90% CI)	90th (90% BI)	95th (90% BI)	Mean (90% CI)	90th (90% BI)	95th (90% BI)
<1 month	89 (64–114)	235* (198–269)	269* (236–332)	153 (125–181)	269* (234–273)	273* (263–332)
1 to <3 months	77 (62–91)	173 (164–217)	246* (187–295)	116 (100–132)	216* (176–259)	291* (214–316)
3 to <6 months	75 (68–82)	156 (145–162)	186 (176–199)	90 (83–97)	161 (145–178)	195* (174–212)
6 to <12 months	59 (54–63)	118 (112–128)	148 (134–166)	63 (59–67)	120 (117–127)	152 (137–166)
1 to <2 years	31 (29–32)	63 (59–68)	85 (73–95)	31 (30–33)	64 (57–67)	86 (70–89)
2 to <3 years	31 (30–33)	59 (57–62)	73 (69–81)	31 (30–33)	59 (56–61)	73 (67–81)
3 to <6 years	29 (28–30)	56 (54–56)	69 (66–72)	29 (28–30)	56 (54–57)	70 (67–73)
6 to <11 years	21 (20–22)	39 (36–41)	50 (47–52)	21 (20–22)	39 (37–41)	50 (46–52)
11 to <16 years	16 (15–17)	31 (29–34)	39 (36–41)	16 (15–17)	31 (29–33)	39 (38–42)
16 to <18 years	15 (13–16)	28 (27–32)	37* (33–44)	15 (14–16)	29 (27–32)	37* (33–44)
18 to <21 years	16 (14–17)	32 (29–35)	41* (36–44)	16 (15–18)	32 (29–35)	41* (36–56)
>21 years	20 (19–21)	36 (35–37)	44 (43–45)	20 (20–21)	36 (34–37)	44 (42–46)
>65 years	21 (20–21)	34 (34–35)	39 (37–41)	21 (20–21)	34 (33–35)	39 (37–41)
All ages	21 (20–21)	38 (38–39)	50 (48–51)	21 (21–22)	38 (38–39)	50 (49–51)

See legend on Table 3.

Table 6. Estimated population size and distributions of body weight by age group: children's fine age categories, adults, all individuals.

			Kilograms[a]									
Age	Sample size	Estimated population	Mean	P01	P05	P10	P25	P50	P75	P90	P95	P99
Less than 1 month	88	214,910	4	1[b]	2[b]	3[b]	3	3	4	4[b]	5[b]	5[b]
1 to <3 months	245	649,444	5	2[b]	3[b]	4	4	5	6	6	7[b]	8[b]
3 to <6 months	411	1,026,107	7	4[b]	5	5	6	7	8	9	10	12[b]
6 to <12 months	678	1,770,700	9	6[b]	7	7	8	9	10	11	12	13[b]
1 to <2 years	1002	4,034,374	12	8[b]	9	9	10	11	13	14	15	19[b]
2 to <3 years	994	3,820,173	14	10[b]	10	11	12	14	16	18	19	22[b]
3 to <6 years	4112	11,644,466	18	11	13	13	16	18	20	23	25	32
6 to <11 years	1553	18,358,891	30	16[b]	18	20	23	27	35	41	45	57[b]
11 to <16 years	975	18,799,441	54	29[b]	33	36	44	52	61	72	82	95[b]
16 to <18 years	360	7,730,899	67	41[b]	46[b]	50	56	63	73	86	100[b]	114[b]
18 to <21 years	383	9,852,117	69	45[b]	48[b]	51	58	66	77	89	100[b]	117[b]
21 years and older	9049	177,681,087	76	45	51	54	63	74	86	99	107	126
65 years and older	2139	30,578,210	72	44	50	54	62	71	81	93	100	113
All ages	19,850	255,582,609	65	8	15	22	52	67	81	95	104	122

Source of data: self-reported body weight data from the 1994–1996, 1998 USDA Continuing Survey of Food Intakes by Individuals (CSFII)
PXX = estimated XXth percentile.
[a]Multiply values by 2.2 to convert to estimated weight in pounds.
[b]The sample size does not meet minimum reporting requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).
Note: 757 individuals did not report body weight. They represent 6,314,627 individuals in the population.

Tibshirani (1993) for a general description of bootstrap intervals. This provides support for use of the general default water ingestion value of 2 l/person/day as a value that represents roughly the 90th percentile of overall ingestion.

The estimated mean daily average per capita community water ingestion by "consumers only" across all ages is 1000 ml/person/day. The 90% confidence interval about the mean is 977–1023 ml/person/day. The estimated 90th percentile from the empirical distribution of daily average per capita community water ingestion for "consumers only" is 2069 ml/person/day and the 90% bootstrap confidence interval around this estimated 90th percentile is 2026–2130 ml/person/day (Table 2, below). This also provides support for use of the general default water ingestion value of 2 l/person/day as a value that represents roughly the 90th percentile of ingestion.

For "all individuals," the estimated mean daily average total water (i.e., water from all supply sources such as

community, bottled, other and missing sources) ingested from all water sources is 1233 ml/ person/day and the 90% confidence interval about this mean is 1200–1265 ml/person/day (Table 3). The estimated 90th percentile from the distribution of total water ingested by "all individuals" is 2341 ml/person/day. The estimated mean daily average ingestion of total water by "consumers only" across all age groups is 1242 ml/person/day. The 90% confidence interval around the estimated mean for "consumers only" is 1210–1274 ml/person/day. The estimated 90th percentile of the empirical distribution of daily average total water ingestion by "consumers only" is 2345 ml/person/day. The default drinking water ingestion value of 2 l/day for an average individual is approximately equal to the 84th percentile for total water ingestion by "consumers only" (see Figure 1).

A gradual increase in mean daily average water ingestion with increasing age past the age of 1 year is suggested by the results summarized in Tables 2 and 3. For example, children in the age range of 1 to <2 years ingest an average of 271 ml/person/day of community water, which is less than the mean 317 ml/person/day ingested by the 2- to <3-year-old age group. For the 3- to <6-year group, the mean ingestion of community water is 380 ml/person/day, whereas the estimated mean daily average community water ingestion by individuals in the 6- to <11-year age group is 447 ml/person/day. The 90% confidence interval about the mean daily average per capita ingestion of community water by 1- to <2-year olds does not overlap that of the 2- to <3-year olds, suggesting that the means are statistically different. Statistical difference is also suggested by the nonoverlapping 90% confidence intervals for mean daily average per capita community water ingestion for the 3 to <6 and 6 to <11 years age groups. This is true for community water and total water ingestion, by "all individuals" and "consumers only."

The mean daily average water ingestion by "all individuals" does not differ statistically for the 3 to <6 months and 6 to <12 months age categories for either community water or total water. However, mean daily average community water ingestion for "consumers only" for these two age categories are statistically different. The mean water ingestion for "all individuals" 3 to <6 months is statistically greater than that of "all individuals" 1 to <3 months for both community and total water ingestion but the means for these same age groups for "consumers only" do not differ statistically.

The largest differences between mean quantity ingested for "consumers only" and "all individuals" are for children and infants in all age categories less than 1 year of age (see Tables 2 and 3). This is especially true for children younger than 6 months of age. However, the effect is less pronounced with total water than with community water. Water from commercially prepared formula or milk is considered intrinsic and, therefore, is not included in the amount of water ingested in this analysis.

Mean water ingestion estimates for the age groups of 16 to <18 and 18 to <21 years are not considered statistically different, because the 90% confidence intervals around the means overlap. This is the case for community water ingestion as well as for total water ingestion, "consumers only" or "all individuals" (Tables 2 and 3). The mean community water ingestion for adults 21 years of age and older is 1104 ml/person/day, and the estimated 90th percentile is 2230 ml/person/day. For "consumers only," the estimated mean community water ingestion is 1183 ml/person/day, and the estimated 90th percentile of the distribution of daily average per capita community water ingestion is 2289 ml/person/day.

The mean total water ingestion for adults aged 21 years and older is 1466 ml/person/day and the estimated 90th percentile is 2553 ml/person/day for "all individuals." These estimates are approximately the same for "consumers only" aged 21 years and older. The estimated mean total water ingestion for adults 21 years of age and older as 1472 ml/person/day and the 90th percentile distribution is 2559 ml/person/day.

When considering total water ingestion by children, a default water ingestion value of 1 l/day for a 10-kg child is often used (e.g., in development of drinking water standards and advisories (US EPA, 2006)). The 1 l/day value is approximately equal to the estimated 90th percentile for children younger than 1 year (3 to <6 months and 6 to <12 months), or up to 6 years of age (3- to <6-year-old group). For the 2- to <3-year-old group, the 1 l/day is between the estimated 90th to 95th percentile distribution of total water ingestion (Table 3).

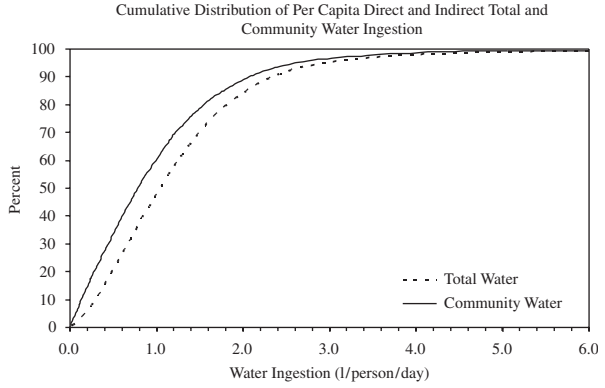

Figure 1. Cumulative distribution of per capita direct and indirect total and community water ingestion by "consumers only." Data source: 1994–1996 and 1998 USDA Continuing Survey of Food Intakes by Individuals (CSFII).

Per Capita Water Ingestion Based on Body Weight: Fine Age Comparison (ml/kg/day)

On the basis of milliliters per kilogram of body weight per day (ml/kg/day), children under 1 month of age ingest, on

average, the largest amount of water of any of the age groups considered. This is true for "all individuals" and "consumers only" estimates of community water (Table 4) and total water (Table 5) ingestion. For example, when all individuals are included, children under 1 month of age have a mean community water ingestion of 52 ml/kg/day. The ingestion rate decreases with increasing age. The difference decreases up to 1 to <2 years of age (mean, 23 ml/kg/day) which is still 50% higher than that of the adults (mean, 15 ml/kg/day). The mean ingestion rate of 11 ml/kg/day (community water) for the age groups of 16 to <18 years olds is the lowest observed. A similar pattern is observed for total water ingestion estimates. On average, children 1 month of age ingest 3.5 and 4.5 times the amount of community and total water, respectively, ingested by adults, when all individuals are included. When only the consumers are used for estimation, a similar pattern is observed. The very young children (<1 month old) ingest the highest average amount of community water or total water, whereas the 16- to <18-month olds ingest the least. Children under 1 month of age, on average, ingest 137 and 153 ml/kg/day community water and total water, respectively, which are approximately eightfold greater than the mean amount of water ingested by adults 21 years of age and above (see Tables 4 and 5).

Distributions of body weights by different age categories self-reported by respondents to the CSFII are shown in Table 6. The body weight values for each respondent were used to calculate the body weight normalized ingestion data summarized in Tables 4 and 5. The average body weight across all individuals is 65 kg. Ten kilograms, often used as the default value for the weight of babies, is equal to the estimated 95th percentile of the distribution of body weights of children in the age category 3 to <6 months. The median weight for the 6–12-month age category is 9 kg and the median weight for the 1–2-year age category is 11 kg.

Discussion

The CSFII survey, which is the source of the data analyzed in this paper, has significant advantages and some limitations for estimating per capita water ingestion. The primary advantage of the CSFII survey is that it was designed and conducted by the USDA to support unbiased estimation of food intake by the population of the 50 States and the District of Columbia. Also, the purposeful oversampling of children provides an abundant source of information of food intake by young people in the overall population. One limitation of the CSFII survey is that individual food consumption data were collected for only two nonconsecutive days—a brief period that does not necessarily yield an accurate picture of "usual intake". Usual intakes are defined as "the long run average of daily intakes of a dietary component by an individual" (see Nusser et al., 1996). It is important to note, however, that variability due to duration of the survey does not result in bias of estimates of overall mean consumption levels. Another limitation is that the multistage survey design does not support calculation of confidence interval estimates for many of the subpopulation means that may be of interest because of sparse representation in the sample. The survey design does, however, support calculation of confidence interval estimates for the US population and some large subpopulations. Also, estimates for other subpopulations of possible interest (e.g., ethnic group, occupational category and geographic area) are not supported by the design of the CSFII, which was devised to obtain a sample of individuals residing in US households by gender, age and income level. In addition, when considering the body weight distributions (Table 6) and the body normalized ingestion values, it is important to be mindful of the fact that body weights were self-reported by respondents to the CSFII. This may introduce a degree of uncertainty into analyses that incorporate the body weight data.

In general, adults over 21 years of age ingest the largest amount of water (community or total water), and children less, with the 1- to <2-year-old group the least, on average, based on milliliters of water ingested per person per day. On a body weight basis (ml/kg/day), the infant consumers ingest the largest amount of water with the amount ingested generally decreasing as age increases. It is noted that the infants younger than 1 month in the "all individuals" group ingest substantially less water than the corresponding "consumers only" group. These young "all individuals" include those who are breast-fed as well as those who are fed with commercially ready-to-drink formula, which are not included in the analysis. Accordingly, the "consumers only" water intake values for infants are considered more representative of the water intake by infants fed with formula either diluted from powered or concentrated mixture.

Direct and Indirect Ingestion by Young Children

Some insight into questions of water ingestion by young children is provided by examining direct and indirect ingestion by age. Summary statistics for direct and indirect community water ingestion by young children are shown in Table 7. A substantial proportion of very young children ingest little or no water, either direct or indirect, presumably because they are breast-fed. For instance, out of a total of 772 individuals sampled that were less than 6 months old, only 152 were reported as ingesting direct water and 405 were reported as ingesting indirect water. Overall, most water ingestion at young ages is indirect through the consumption of baby formula or juice reconstituted from powder or concentrate by dilution with water. This is demonstrated by the mean ingestion amounts shown in Table 7. The largest value, 546 ml/person/day, is the mean indirect ingestion for

Table 7. Estimated mean community water direct and indirect ingestion for young age groups.

	Community water ingestion for young age groups					
	Sample size	Population	Mean (ml/person/day)	Sample size	Population	Mean (ml/person/day)
Age	Consumers only: direct			Consumers only: indirect		
Less than 6 months	152	379,488	107	405	985,944	546
6 to <12 months	269	684,284	159	540	1,378,567	408
1 to <2 years	605	2,451,417	246	854	3,403,203	158
2 to <3 years	655	2,551,296	292	891	3,427,758	156
	All individuals: direct			All individuals: indirect		
Less than 6 months	772	1,957,390	21	772	1,957,390	275
6 to <12 months	714	1,864,971	58	714	1,864,971	302
1 to <2 years	1040	4,184,268	143	1040	4,184,268	128
2 to <3 years	1056	4,036,268	185	1056	4,036,268	132

Data source: 1994–1996 and 1998 USDA Continuing Survey of Food Intakes by Individuals (CSFII).

the youngest age group (less than 6 months) for ''consumers only''. The mean for direct ingestion for the less than 6 months group, consumers only, is 107 ml/person/day. As age increases, the indirect ingestion mean decreases and the direct mean increases reflecting the pattern of decreased use of baby formula and increased direct ingestion as children grow older. The pattern of ingestion in the results for ''all individuals'' is similar to that for ''consumers only'' with the effect of including sampled individuals with no reported ingestion readily apparent.

Per Capita Water Ingestion Based on Body Weight: (ml/kg/day)

On the basis of kg body weight, the young children under 1 month of age have, on average, the highest water ingestion (community or total water, see Tables 4 and 5) of all the age groups. On the basis of body weight, consumers younger than 1 month of age ingest, on average, approximately eight times the amount of water as the adults (Tables 4 and 5). Although ''all individuals'' in this age group ingest only three times the amount of water compared with the adults, it is the value for the ''consumers only'' that is considered to better represent ingestion of infants who are fed with formula made from concentrated or powered mixture. The ''all individuals'' infant category includes those who are breast-fed and those who drink only the ready-to-drink formula, which is not counted in the analysis.

Estimates of Percentiles of the Distribution of Ingestion by Selected Populations

The results discussed here provide a means for evaluating water ingestion values for use in risk assessment work or other analyses where water ingestion is a key variable, for example, evaluation of demand for public drinking water supplies. In risk assessment, often a value is specified, or assumed, to represent water ingestion for a population or subpopulation. Risks to the population from ingestion of contaminated water are estimated on the basis of the assumed ingestion rate and a range of contaminate levels. The observed distributions of water ingestion (US EPA, 2004) may be used as the basis for selecting an ingestion rate or a selected rate can be compared with the overall distribution to place it in some overall context. This is a critical step in the risk assessment process that supports informed judgment regarding the results of a risk assessment and implementation of risk management decisions. For example, in risk assessment analyses, a common practice has been to use 2 l/person/day as a default value to represent water ingestion for a typical 70-kg person. The 2-l/person/day value may be placed in context using the ingestion distributions. For instance, the cumulative distributions of per capita direct and indirect ingestion of total water and community water by ''consumers only'' are shown in Figure 1. From the Figure, it can be seen that the value of 2 l/person/day is approximately equal to the observed 89th percentile of the cumulative distribution of per capita direct and indirect community water ingestion by ''consumers only'' and the observed 84th percentile of per capita direct and indirect total water ingestion by ''consumers only''.

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